PREFACE

This book is the result of several years' experience of the authors with the Intermediate classes. A lot of time is usually wasted in giving instructions and notes to the students as to the procedure of the day's work. The authors feel that this humble attempt at systematizing the practical work of Intermediate classes, will go a long way to remove this difficulty.

The Syllabus of the Punjab University has been strictly followed in this scheme.

The authors take this opportunity to thank Professor Mehr Chand Sethi, M. Sc. Professor of Botany, Forman Christian College, Lahore, for his valuable guidance and assistance. Their thanks are also due to Professor Ganga Ram Kohli, M. Sc., Dyal Singh College, Lahore, and Professor Jiwan Singh, M. Sc., Khalsa College, Amritsar, for their helpful criticism of the manuscript.

Amritsar,
1934.

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CONTENTS

EQUIPMENT

The student should provide himself with the following things for practical work in Botany :—

1. A drawing pencil and an eraser.
2. A set of instruments comprising the following :—
   (*a*) Scalpel (large and small)
   (*b*) Forceps (large and small)
   (*c*) A couple of mounted needles.
   (*d*) A pocket lens.

PARTS OF THE PLANT.

Uproot a small sunflower plant from a flower pot and note the following parts :—

1. **Root System** : The lower part of the plant axis consists of a main root, bearing smaller roots upon it. Note that the main root and the smaller roots are not coloured, and together constitute the *Root-system*, which serves to fix the plant in the ground and also to absorb water from the soil.

2. **Shoot, Stem and Leaves**: The aerial parts of a plant, as a whole, constitute the *shoot*. The branched axis of the shoot is the *stem*, and the broad green appendages borne on the stem are the *leaves*.

The leaves are the kitchens of the plant where its food is cooked. The energy of the Sun's rays serves as the fuel. The stem and its branches function, firstly to conduct to the leaves, the raw food material absorbed by the roots, and secondly to bear the leaves so as to expose them well to the sun.

3. **Axil, Axillary**: The angle between the stalk of a leaf and the stem is known as an *axil*. Note a small projection-like bud in the axil. It will later develop into a lateral branch. The bud is known as *axillary*. Note other axillary buds at various stages of development.

4. **Terminal Bud** : At the extreme end of the stem is a compact structure formed by the overlapping of the young, unfolded leaves. Lying protected amidst these young leaves is the growing point of the stem. The whole structure is called the *terminal bud*.

5. **Flowers** : The flowers of the sun-flower plant are rather small and aggregated together into compact groups. The flowers form seeds, which are capable of forming new plants of the same type. The flowers are the reproductive parts of a plant.

MORPHOLOGY OF THE SEEDS.

To prepare the seeds for study, soak them in water overnight.

1. **Seed of Almond**: A single seed is found within a hard fruit part. The seed has a brown seed-coat or *testa*, and a white, thin membrane called *tegmen* within it. On the removal of the seed-coat and tegmen come to view two white masses, the *cotyledons*, wedged between and attached to which is a small *embryo*. It consists of a *radicle*, projecting out from between the two cotyledons, and a leafy shoot or the *plumule*. The two cotyledons are attached to the axis of the embryo by small stalks, and are in fact the first two leaves of the embryo. They serve for storage of food material.

2. **Seed of Water-melon** : The seed has a hard, black or red testa. On its removal, note the same structures as in the seed of almond.

3. **Seed of Pea** : At one end, on the surface of the testa, there is a prominent, narrow scar, marking the point of attachment in the fruit, known as the *hilum*. Very close to it is a small aperture, the *micropyle*, from which a drop of water oozes out, if a soaked seed is pressed. Enclosed within the testa are two massive cotyledons and a small embryo.

4. **Seed of Gram** : The seed is somewhat conical, tapering abruptly to a sharp point. Note a conspicuous scar-like hilum and a micropyle lying between the hilum and the pointed end of the seed. Remove the black or brown testa and note the parts as in the seed of Pea.

5. **Seed of Castor-oil :** The testa is very hard and spotted and bears a swollen, glandular outgrowth at one end, the *aril*, which absorbs water and helps to break the hard testa. Tegmen is also present.

After the removal of the seed coat, you come across a white mass of food material, the *endosperm*. Split the endosperm longitudinally into two and note an embryo and two thin leaf-like cotyledons. The radicle is blunt and knob like.

The cotyledons in this seed do not serve for storage, the seed is albuminous.

6. **Maize Grain :** Each grain is somewhat conical and flattened on two surfaces where it has been in touch with the other grains on the cob. The maize grain is a fruit, enclosing a single seed.

The fruit wall or the pericarp is fused with the testa of the seed. Note oblong white areas on the flat surfaces of the seed. Place the seed on one of its flat surfaces and give a cut at right angles to this surface, passing through the conical end.

Note that the narrow end is occupied by a massive embryo consisting of a radical and a plumule, wrapped in several sheaths. The whole upper white area is the endosperm. The outer layer of the endosperm, next to the fused testa and pericarp, is the *aleurone layer*.

Note a single membrane-like cotyledon, the *scutellum*, between the embryo and the endosperm. It serves as an absorbtive organ.

GERMINATION OF THE SEEDS.

Place a few seeds, (of Water-melon, Gram, Castor-oil and Maize) covered with moist saw dust, in a dish. They begin to germinate in two or three days.

1. **Water-melon.** Note that the radicle elongates and is the first to emerge out, breaking through the seed-coat, at the pointed end of the seed. It forms the main or the primary root. Note that the cotyledons are *epigeal, i. e.,* they are lifted above the ground, and become green. The part of the axis below the cotyledons shows very active growth and is called the *hypocotyl.* It is curved in young seedlings. The plumule unfolds its branches and leaves.

2. **Gram.** The radicle breaks through the softened testa and goes deep into the soil. The hypocotyl remains curved for some time, to protect the delicate parts of the plumule against the friction of the soil, but straightens up gradually, as it grows. The cotyledons are not taken up above the ground and are termed *hypogeal.*

3. **Castor-oil.** The hypocotyl forms a prominent arch. The leafy cotyledons remain within the seed for some time, but enlarge and come out, as the hypocotyl straightens, to form the first batch of the green leaves.

4. **Maize.** The radicle and the plumule pierce through the fused pericarp and testa in opposite directions. The scutellum is hypogeal. Note that the axis is not curved ; the plumule is pointed like a lance and is able to pierce the soil successfully. In advanced stages of germination, a number of small roots may be seen arising from the base of the shoot.

MORPHOLOGY OF THE STEM.

I. Buds:

1. Examine the terminal portion of a shoot of *Banyan* or *Pipal.*

Note the *nodes* or the places from where the leaves arise, and the *internodes* or the leafless stretches of the stem. One leaf arises from each node. There are two scars, one on each side of the insertion of the leaf stalk on the stem. This is from where the *stipules* have fallen off. The stipules can be seen in the leaves of the terminal bud. Note that they are large, brown or purple in colour, and cover the comparatively small and young leaves. Remove them one by one to see their arrangement.

Cut a transverse section of the terminal bud with a sharp razor and note the arrangement of the overlapping leaves and their stipules.

2. Examine a branch of Pear or Peach before the floral season and note the winter buds.

II. Forms of the Weak Stems:

1. **Climbing Stems of Vine.** The plant is a large woody climber. The stem raises itself on supports through the agency of long, slender, climbing organs, the *tendrils*. Note that the tendrils are coiled like a spring, which protects them from breaking off the supports. The tendrils arise opposite to the leaves.

Other examples of climbers are the many *Cucurbita* plants, (*Kadoo, Tar* and *Kharbuza* etc.,) the Garden Pea, *Ivy, Smilax* and *Clematis*.

The Cucurbita Stem is frail and climbs up by very much coiled tendrils. Note the position of the tendrils; they arise in the axils of the leaves.

2. **Twining Stems of Convolvulus** (vern, *Hirun Khuri* or, *Krari*). The plant grows wild in wheat and cotton fields, and can be recognised by the arrow-head shape of the leaves. Note that there are no special climbing organs. The stem is thin, delicate and attains an erect position by twining around the wheat or cotton plants, in a spiral manner. The growing tip of the stem curves around the support, as it elongates, and the support is thus tightly caught hold off.

Stem of *Ipomœa* (vern, *Ishkpecha*), is another example. It climbs up on supports by twining, and is very commonly cultivated in the houses and on the Railway Stations.

3. **Prostrate Stems of Euphorbia Prostrata** (*Wild dodak*), and *Convolvulus pleuricaulis* (vern, *Sankhavli*).

Note that the branches spread themselves on the ground. They form a rosette or a whorl around a central strong taproot.

4. **Creeping stem** of grass (vern, *Tiran*).

Locate a tuft of grass, and note that one or more long, slender, spreading shoots arise from the axils of small scale leaves, and run in various directions. These prostrate shoots are called the **Runners.**

Note that a runner bears scale leaves and even buds, which form more tufts of grass.

In *Strawberry*, the runners are long and slender, and become rooted at the nodes. Note their axillary origin, and also the scale leaves and the buds that they bear.

III. Underground Stems :—

1. **Suckers of Mint** (*Mentha, Podina*).

In Mint special shoots arise, resembling the runners of grass, and become underground. They are not green, arise in the axils of leaves and bear scale leaves and even buds. The sucker and its branches may burrow for short distances, but emerge out sooner or later and develop into green leafy shoots. Note the roots developed at some nodes.

2. **Offsets of Furcrea.**

The plant is grown in the gardens. It has a short axis and large succulent leaves resembling *Kawargandal*. The leaves show beautiful variegation.

Special short, stout, underground branches are formed which develop buds at their tips, and form new plants.

Note the closely growing plants of Furcrea in a garden plot. They are all connected by underground shoots or offsets. Note the scale leaves on the offsets.

3. Rhizome of Ginger.

It is a thick, branched, underground stem. Note the light brown colour and conspicuous scars. There are many brown scale leaves; some of them show buds in their axils. The thickness is due to the stored food material. The scars indicate the position of the aerial shoots which have died. Note a growing point, which helps the rhizome to elongate.

Study rhizomes of *Saccharum* (vern, *Káhi, Kánâ*), *Banana*, and *Lotus plant*,

4. Corm of Freesia.

It is a condensed form of rhizome, which has no power of elongation, and is fixed by roots. It bears scale leaves and buds. A terminal bud usually develops into an aerial floral shoot, and is surrounded at its base by several green leaves. The food assimilated by the current year's shoot becomes stored at its base and forms the next year's corm. By the time the new year's corm is formed, the last year's corm may still be seen at its base in a somewhat shrivelled condition. Sometimes corms of three successive generations may be seen one above the other.

5. Bulb of Onion.

It consists of a small, dwarf, disc-like stem, enclosed within the overlapping fleshy leaf bases.

Cut a bulb longitudinally and note the disc and the leaf bases. One or more buds may be noticed arising in the axils of the fleshy leaf-bases. Note the adventitious roots arising from the base of the disc.

On maturity the outermost leaf base becomes dried and forms a corky, membranous pink *tunic* for protection. The bulb is, therefore, called a *tunicated bulb.*

Note that the leaf of onion performs a double function; its upper green cylindric portion manufactures the food material, while the broad leaf-base stores it.

7. Bulb of Garlic.

It has a similar disc-like stem and two types of leaves: green, cylindrical, manufacturing leaves, and small, fleshy, storing scale leaves. The bulbous structure in this case being the result of the aggregation of fleshy scale leaves, is known *as a scaly bulb.*

Note a similar structure in the bulb of a species of *Oxalis* (*wood sorrel, khathkal*).

IV. Special Modifications of Underground Stems:

Stem tuber of Potato.

It is a swollen or distended tip of a special underground shoot or its lateral branches. In appearance it is highly unlike a stem, but it can be recognised to be so, firstly by the buds found in its small depressions, and secondly by the brownish scale leaves.

Cut a Potato tuber and note the corky nature of its brown covering. The small depressions with buds in them are known as *Eyes.*

Note similar stem tubers in *Colocasia* (*Kachalu*), stem tubers feed their buds to enable them to become full plants.

V. Special Modifications of Aerial Stems:

1. Stem tendrils of Vine (vern, *Angur*).

Take a shoot of vine and note that a tendril is found opposite to a leaf. The tendrils are the modified shoots of a cymosely branched stem.

Note that the tendrils of *Cucurbita* are the modified axillary shoots.

2. Stem spines of Duranta.

Take a branch of *Duranta* or the *Hedge-plant*, and note the spines in the axils of leaves. The spines are the modified axillary shoots, which is proved by the fact that they sometimes bear leafy buds.

Note that the thorns of *Citrus* are also modifications of axillary shoots.

3. **Phylloclades of Opuntia** (vern, *Chhitar thor*).

Note the flattened, succulent, green shoots of Opuntia. They bear scars from where the leaves have fallen off. The bristly areas are known as **aeroles.**

In *Ruscus* (*Butcher's broom*), note that the true leaves are in the form of small, dry, membranous, linear structures found on the main stem. The broad green, apparently leaf-like structures are the *Phylloclades.* Note that they arise in the axils of the scaly leaves and are the modifications of axillary shoots. Moreover they bear scale leaves and buds.

Another example is *Asparagus* in which the cladodes are represented by tufts of green needle-like structures arising in the axils of smale scale leaves.

4. **Bulbils of Agave.** (*Century plant*, vern, *Jangli Keurá*).

The flowers of Agave are aggregated at the top of a large leafless axis, arising from amidst a whorl of large leathery leaves. In place of flowers arise very commonly large, axillary, green, vegetative buds, which can be recognised from a distance by their leafy appearance. Note the thick succulent overlapping leaf bases, with stored food.

The bulbils differ from ordinary buds in their being capable of detaching from the parent plant and developing into new independent plants ; soon after its fall on the ground, the bulbil forms adventitious roots at its base.

Note similar special buds arising in place of the flowers of *Furcrea*, and in the axils of the old leaf bases of *Cycas.*

5. **Torus or Thalamus.** It is that region of the central axis of the flower on which the floral leaves are inserted.

MORPHOLOGY OF THE ROOT.

I. Tap root-system. Examine a young *Sun-flower* plant, freshly uprooted from a flower pot. Note a central thick tap root with numerous lateral branches. Note that the lateral roots bear, near their tips, fine, hair-like structures called *root-hairs*. Their brownish cap-like covers may be seen at the tips of some lateral roots, especially when the digging and washing has been done carefully.

The tap and its lateral rootlets form the tap-root system. Note that the youngest rootlets are near the tip of the tap-root. (*ocropetal order.*)

II. Adventitious roots. Examine a young plant of Maize or Wheat, and note the numerous roots arising together from the base of the stem. These roots do not seem to follow any arrangement of proper sequence according to age and are described as *adventitious*.

1. **Fibrous adventitious roots of sugar-cane.**

Note the strong, thin, adventitious roots arising from several lower nodes of the stem. They are *fibrous* in nature.

Note similar roots in *Sorgham* (vern, *Chari*), *Saccharum* (vern. *Kaná* and *Káhi*), and grass.

2. **Tuberous adventitious roots of Asparagus, and Dahlia.**

Uproot a plant of Asparagus, and note a bunch of several, thick, white roots, containing a large amount of stored food. These tuberous roots serve for perennation, during unfavourable seasons.

3. **Aerial adventitious roots of Banyan, and Pipal.**

Note thick branching clusters of slender aerial roots, hanging from the under surface of the branches of the stem. Note their succulent, brittle nature. The peripheral layers of these roots are hygroscopic in nature and serve to absorb the moisture from the air.

Pipal also bears such aerial roots. In due course these roots may reach and penetrate the soil and function as normal roots.

III. Modifications of a Tap-root.

The tap root may attain various forms on account of the storage of food material, and may only bear a few small lateral roots.

1. **Conical tap root** : in Carrot and Radish ; thick above and tapering downwards.
2. **Fusiform tap root** : in English radish thick in the middle and tapering towards both ends.
3. **Napiform tap root** : in Turnip ; thick in the middle and abruptly tapering towards both ends.

Type : **Funaria**

It is a small erect leafy plant fixed to the soil by means of rhizoids which are branched, septate and brown in colour. Wash a few young leafy shoots carefully, and note amongst the rhizoids green, branched, filamentous *Protonema*. The leafy shoots arise from this underground protonema as buds. Examine and note that the leaves are simple with serrate margins. The cells in the lamina have numerous chloroplasts, some of which may be seen in a dividing state. From the apex of some female plants may be seen arising the sporogonium borne on a long stalk.

Examine a T. S, of the stem. Note the central cylinder of thin-walled cells surrounded by wide thin-walled cells. The outermost layer of cells is the epidermis. Note the thick-walled cortical cells inner to the epidermis.

Take out an antheridium from within the apical rosette of leaves in a male shoot. Note, a club-shaped structure borne on a short stalk. Press the coverslip and see the antheridium emptying itself. If it is ripe, the wriggling sperms may be examined.

Examine a separated archegonium from within the apex of the female shoot and note the large venter and the long neck with a row of neck canal cells. The oosphere may be seen in the venter.

Examine the L. S. of the sporogonium and note the upper *operculum*, middle *body*, and the lower tapering *apophysis*. The operculum is held in position by a ring of cuticularised epidermal cells, the *annulus*. In the body may be examined spore sacs containing spores around a central columella, and an outer air space. Note ring-shaped stomata on the surface of the apophysis.

3. **Leaf of Oleander.** (*Kaner*)

(*a*) (*g*)

(*b*) (*h*)

(*c*) (*i*)

(*d*) (*j*)

(*e*) (*k*)

(*f*)

4. **Leaf of Convolvulus** (vern, *Hiran khuri*) Alternate ; ramal and cauline ; simple ; lasting with plant ; petiolate ; exstipulate ; lamina incompletely incised into three lobes, a large forwardly directed and two basal outwardly directed lobes (*hastate*) ; unicostate, reticulate; wavy ; acute ; smooth ; herbaceous.

5. **Leaf of Garden Nasturtium** (*Tropaeolum*).

(*a*) (*g*) Multicostate, reticulate.

(*b*) (*h*)

(*c*) Lasts with the plant. (*i*)

(*d*) (*j*)

(*e*) (*k*)

(*f*) Peltate, orbicular.

6. **Leaf of Calatropis** (vern, *Ak*)

(*a*) Opposite, decussate, ramal and cauline. (*g*)

(*b*) (*h*)

(*c*) (*i*)

(*d*) (*j*) Covered with a wax (mealy)

(*e*) (*k*)

(*f*) Oval or elliptic

7. **Leaf of Ocimum Sanctum** (vern, *Tulsi*).

(*a*) Opposite, decussate, ramal and cauline.

(*b*) (*g*)

(*c*) (*h*)

(*d*) (*i*)

(*e*) (*j*)

(*f*) (*k*)

8. **Leaf of Castor-oil.**

(*a*) (*g*) Multicostate, reticulate.

(*b*) Simple. (*h*)

(*c*) Petiolate, the petiole bears two glands. (*i*)

(*d*) (*j*)

(*e*) Stipulate, stipules fall off. (*k*)

9. **Leaf of Mulberry.**

(*a*) (*e*) Stipulate.

(*b*) (*f*)

(*c*) (*g*) Pinnatisect or pinnatipartite.

(*d*)

10. **Leaf of Banana** (vern, *Kela*).

(*a*) Alternate, arising from rhizome. (*g*) Unicostate, parallel.

(*b*) Simple. (*h*)

(*c*) (*i*)

(*d*) Sessile, overlapping leaf bases form a false stem. (*j*)

(*e*) (*k*)

(*f*) Lanceolate-o-linear.

11. **Leaf of Wheat.**

(*a*)

(*b*)

(*c*)

(*d*)

(*e*) Leaf base sheathing, ligulate.

(*f*) Linear.

(*g*) Multicostate, parallel.

(*h*)

(*i*)

(*j*)

(*k*)

12. **Leaf of Saccharum** (vern., *Káná*)

(*a*)

(*b*)

(*c*)

(*d*)

(*e*) Leaf base sheathing, ligulate,

(*f*)

(*g*)

(*h*)

(*i*)

(*j*)

(*k*)

13. **Leaf of Canabis** (vern., *Bhang*)

(*a*)

(*b*) Simple.

(*c*)

(*d*)

(*e*)

(*f*) Lobes lanceolate.

(*g*)

(*h*) Palmatisect. (lobes without definite articulations).

(*i*)

(*j*)

(*k*)

14. **Leaf of Russelia.**

(*a*) Whorled, whorls of three or more.

(*b*) Simple.

(*c*)

(*d*)

(*e*)

(*f*)

(*g*)

(*h*)

(*i*)

(*j*)

(*k*)

15. **Leaf of Radish.**

(*a*) Radical, appearing to spring from the root. (*g*)

(*b*) (*h*)

(*c*) (*i*)

(*d*) (*j*)

(*e*) (*k*)

(*f*) Lyrate with a large, rounded, terminal lobe, and smaller lower lobes.

16. **Leaf of Launaea.** (vern., *Pili dodak*)

(*a*) Radicle.

(*b*) Simple. (*g*)

(*c*) (*h*)

(*d*) (*i*)

(*e*) (*j*)

(*f*) Runcinate with a large acute terminal lobe, (*k*) and smaller lobes directed backwards.

Sequenre of items in the description of a compound leaf.

17. **Leaf of Rose.**

(*a*) Insertion : alternate, ramal and cauline.

(*b*) Kind : compound, pinnate, imparipinnate.

(*c*) Duration : deciduous.

(*d*) Petiole : petiolate.

(*e*) Stipules : stipulate, stipules cohering with the petiole (adnate).

(*f*) Number of leaflets ; 3 or 4 pairs and a terminal unpaired leaflet.

(*g*) Petiole of leaflet : petiolate.

(*h*) Form of leaflet : oval or elliptic.

(*i*) Venation : unicostate, reticulate.

(*j*) Margin : serrate.

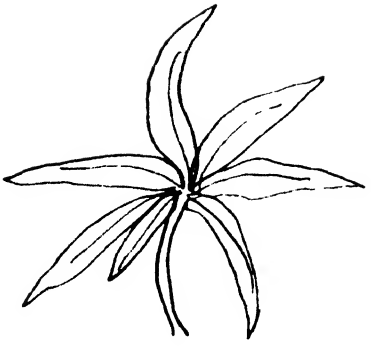
(*k*) Apex : acute.

(*l*) Surface : glaucous.

(*m*) Texture : herbaceous.

18. **Leaf of Cassia fistula** (vern, *Amaltas*).

(*a*) Alternate, ramal.
(*b*) Compound, pinnate, paripinnate.
(*c*) Deciduous.
(*d*)
(*e*)
(*f*) Four or more pairs
(*g*) Petiolate.
(*h*)
(*i*)
(*j*)
(*k*)
(*l*)
(*m*)



19. **Leaf of Bombax malabaricum** (vern, *Symbal*).

(*a*)
(*b*) Compound, palmate, multifoliate.
(*c*)
(*d*)
(*e*)
(*f*)
(*g*)
(*h*)
(*i*)
(*j*)
(*k*)
(*l*)
(*m*)

20. **Leaf of Pea**

(*a*)
(*b*)
(*c*)
(*d*)
(*e*)
(*f*)
(*g*)
(*h*)
(*i*)
(*j*)
(*k*)
(*l*)
(*m*)

21. **Leaf of Acacia arabica** (vern, *Kikar*)

(*a*) Alternate.
(*b*) Compound, bipinnate, leaflets, paripinnate.
(*c*)
(*d*)
(*e*) Stipulate, stipular spines.
(*f*)
(*g*)
(*h*)
(*i*)
(*j*)
(*k*)
(*l*)
(*m*)

22. **Leaf of Citrus.**

(*a*)

(*b*)

(*c*)

(*d*)

(*e*)

(*f*)

(*g*)

(*h*)

(*i*)

(*j*)

(*k*)

(*l*)

(*m*)

23. There are two types of compound leaves, the pinnate, and the palmate, and they correspond respectively to the reticulate unicostate, and reticulate multicostate simple leaves, from which they have arisen by a progressive breakage of the lamina.

To understand this, arrange the following two series of leaves and sketch.

(*a*) Reticulate, unicostate simple leaf. ⟶ Pinnate compound leaf.
Jaman, Oak, Mulberry, Radish and Rose.

(*b*) Reticulate, palmate simple leaf. ⟶ Palmate compound leaf.
Malva, Cotton, Castor-oil, Canabis and Bombax.

24. **Compare a branch of *Duranta* and compound leaf of *Rose*.**

Branch of Duranta.	**Compound leaf of Rose.**
(*a*) It arises in the axil of a leaf.	(*a*) Not so.
(*b*) It bears several leaves.	(*b*) It bears several leaflets.
(*c*) It has nothing in its axil.	(*c*) It has a branch or a bud in its axil.
(*d*) It has buds in the axils of leaves.	(*d*) It has no buds in the axils of leaflets.
(*e*) It has a terminal growing point.	(*e*) It has no growing point.

MORPHOLOGY OF THE FLOWER.

1. **Ranunculus** (*Buttercup*).

Flowers are ebracteate, pedicellate, complete, actinomorphic, hermaphrodite and hypogynous. The calyx consists of five sepals quite free from one another (*Polysepalous*) and bent back. The corolla is polypetalous with five bright, yellow petals; petals alternate with the sepals, and each has got a pocket-shaped nectary on the upper surface at the base. The stamens are numerous and free (*polyandrous*). Note the parts of the stamens *i.e.*, *filament*, *connective* and the *anther lobes*. The pistil consists of numerous, free carpels (*apocarpous*). Note the parts of the carpel *i.e.*, basal swollen *ovary*, with a short *style*, and a minute terminal *stigma*. The ovary is unilocular and superior.

Sketch the V. S., of flower and draw the floral diagram.

2. **Wall-flower** (*Cheiranthus*).

Flowers are ebracteate, pedicellate, complete, regular, hermaphrodite, actinomorphic and hypogynous. The calyx consists of 4 free sepals arranged in two whorls. The corolla of 4 petals, polypetalous and cruciform. The stamens are 6 in number in two series *i. e.*, two outer short and 4 inner long arranged in pairs (*tetradynamous*). Note small, knob-like nectaries at the base of the stamens. The pistil is bicarpellary, syncarpous. The ovary is superior, bilocular due to a false septum, with parietal placentation.

Sketch the V. S., and the **floral diagram** of the flower.

3. **Rose.**

The flowers are pedicellate, complete, hermaphrodite and perigynous. Note that there is a conspicuous tube formed by the thalamus. The calyx is persistent, gamosepalous, and five lobed. The corolla consists of numerous free petals. Stamens free and indefinite. Note the numerous free carpels arising from the inner surface of the cup-shaped thalamus and the long styles seen protruding out from the thalamus tube.

Sketch the V. S., and the **floral diagram.**

4. **Delphinium ajacus** (*Larkspur*).

Flower is pedicellate, irregular and zygomorphic. Note that the calyx is polysepalous (5 sepals) ; the posterior sepal forms a long spur which covers the spur of two posterior petals in which the honey is secreted. Stamens are numerous and the pistil is monocarpellary, with superior ovary.

5. **Althea rosea.** (*Gul-a-Khaira*)

Note that below the calyx there are 5-6 bracteoles constituting *epicalyx*. Calyx is gamosepalous, persistent. Corolla consists of 5 free petals (*polypetalous*) with twisted aestivation. Note that there are numerous stamens, fused to form a staminal tube (*monoadelphous*) which is fused with the petals at the base. Pistil polycarpellary, syncarpous, with superior and multilocular ovary.

6. **Ipomoea.**

Calyx is gamosepalous with 5 sepals. Corolla is gamopetalous, funnel-shaped, and the number of the petals is indicated by the lobes. Stamens five and epipetalous. Pistil bicarpellary : note two long stigmas. Ovary is bilocular with axile placentation.

7. **Petunia.**

Calyx is gamosepalous and the corolla is gamopetalous. Note epipetalous stamens. Pistil is bicarpellary with a bilocular ovary.

TYPES OF INFLORESCENCES.

I. If the flowers occur singly, they are termed *solitary axillary* or *solitary terminal.* Study a few flowering *Poppies* and note that each shoot ends terminally into a flower ; the flower is described as *solitary* and *terminal.*

II. Racemose Inflorescences.

The flowers are borne on an axis which as it grows forms more and more flowers laterally. The axis has thus an incessant power of growth.

1. **Simple Raceme** of *Cassia fistula* :

Note that the mother axis (*peduncle*) is elongated, and bears pedicellate flowers, the youngest being at the apex. Note the simple racemes in *Linaria*, *Larkspur* and *Radish.*

2. **Corymb** of *Candytuft.*

The axis of the inflorescence (*peduncle*) is elongated, and bears pedicellate flowers. The pedicels of the lower flowers are longer than those of the upper ones, and all the flowers come to lie at the same level.

3. **Cheiranthus** (*wall flower*).

Note that the inflorescence is a typical raceme below and gradually approaches a corymb at the top.

4. **Spike** of *Callestemon* (*Bottle brush*)

The mother axis is long, and bears sessile flowers at short distances.

5. **Umbel** of *Calatropis* (*Ak*)

Note that the flowers have a closer insertion and form a whorl of pedicellate flowers.

6. **Catkin** of *Morus* (*Mulberry*).

The flowers are unisexual and arranged in the manner of a spike. The axis is slender and pendulous. There are male and female catkins.

7. **Panicle** of *Dalbergia sissoo* (vern, *Shisham*).

Note that the main peduncle is branched repeatedly, in an irregular manner. Each ultimate branch is a short raceme.

Other examples are *Azadirachta indica* (*Neem*), and *Asphodelus* (*Piazi*).

8. **Spadix** of *Phoenix dactylifera* (vern, *Date-palm*). The axis of the inflorescence is branched repeatedly, and bears sessile, unisexual flowers. Note that the whole inflorescence is enclosed within a large woody bract or *Spathe*, which opens on the two sides.

Arum lily is another example of spadix. The spathe is white or slightly coloured and forms a background for a columnar axis bearing unisexual, sessile flowers.

9. **Umbel** of **Umbels** or **Compound Umbel** of *Fennel* (vern, *Saunf*).

The main axis forms a whorl of peduncles, surrounded by a collection of bracts (*involucre*), and each peduncle at its tip bears several pedicellate flowers in an Umbellate manner.

Other examples are *Carum* (*Zira*), *Daucus Carrota* (*Gajar*), and *Coriandrum* (*Dhania*).

10. **Capitulum** of *Helianthus annus* (*Sun-flower plant.*) The floral axis is flattened, disc-shaped and covered with sessile flowers. The disc is surrounded by a number of small scaly leaves forming the *involucre.* The flowers on the top of the disc are of two kinds. The outer peripheral flowers are ligulate, neuter, and known as *Ray florets.* The central flowers are tubular, bisexual and known as *Disc florets.* Note that the disc florets are epigynous, with gamopetalous corolla and epipetalous stamens. The cohesion of the stamens is by anthers *i.e.*, *Syngenesious*, and the calyx is in the form of *pappus.* Ovary is inferior.

Sketch the V. S. of the receptacle and the florets.

11. **A Closed Capitulum** or **Hypanthodium** of *Ficus bengalensis* (vern, *Banyan*).

The axis forms a hollow structure, opening by an aperture at the top. Note a number of bracts projecting into the cavity guarding the opening. The flowers are Unisexual and arranged on the inner surface.

Male flowers are situated near the opening while the female flowers are scattered in the lower part.

(III) Cymose infloresceneces.

The main axis terminates in a flower.

1. **Althea rosea** (*Hollyhock*).

Note three flowered dichasial cymes in the axils of the ordinary foliage leaves. The main axis ends in a flower, giving off a flower on either side. Sometimes five flowers may be noticed.

2. **Silene** (vern, *Takla*).

Note that the main axis ends in a flower and has two bracts, each of which has further got a branch in its axil. Each of these branches ends in a flower and produces two other branches in the axils of its bracts and so on. Such a bifurcating inflorescence is known as *Dichasium*.

Other example is *Stellaria media* (*Gandhél*).

IV. Special Inflorescences.

1. **Verticillaster** of *Ocimum basilicum.*

The leaves are opposite and decussate and in the axils of each leaf there is a whorl of flowers. Note that in each whorl there is an oldest flower in the centre with two young ones at the sides. This whorl is a dichasium of scorpiod cymes *i.*, *e.* a biparous cyme which passes on either side into a uniparous form by suppression of one of the branches at each branching.

Other examples are *Mint* and *Salvia.*

2. **Cyathium** of *Euphorbia helioscopia.*

The inflorescence has got two bracts at the base. Note the cup-shaped involucre within these bracts, and the leafy glands on the margin alternating with the bracts. Split involucre lengthwise, and note the tricarpellary, syncarpous ovary borne on a long stalk coming out of the centre, surrounded by numroeus stamens. The pistial is in fact a reduced pistillate flower. Note a joint in its stalk. Examine one stamen carefully, and note a joint above the middle. It is a reduced staminate flower.

I. **Simple dry achenial fruits.**

(1) **Achenes** of *Ranunculus.*

The fruit is a cluster of typical *achenes*, and is known as *Etaerio of achenes.* Note that each achene has got an outer tough cover enclosing one seed.

(2) **Cypsella** of *Sonchus* (vern, *Dodak*).

Note that the small fruit is crowned with a tuft of hairs—*pappus*, and encloses one seed. The pappus is a modified calyx.

(3) **Caryopsis** of *Maize.*

Note that the pericarp and the testa of the seed within are fused and inseparable. The embryo may be examined towards one end of the seed.

(+) **Smara** of *Elm* (vern, *Sahiá*).

Note a single seed at the centre of the flattened wing like pericarp.

(5) **Nut** of *Oak.*

Note that the pericarp is hard and woody. Towards one end of the fruit may be noticed a cup-shaped structure formed by the fusion of bracteoles, known as the *cupule.*

II. **Simple dry Capsular fruits.**

(1) **Follicle** *of Larkspur.*

Note that the fruit opens by a slit along one suture (ventral) and the seeds are arranged along the other (dorsal).

(2) **Legume** of *Pea.*

Note that the fruit dehisces along both edges. The seeds are seen along one margin only, indicating its development from a monocarpellary pistil.

(3) **Siliqua** of *Mustard.*

It is a cylindrical fruit. Note that it dehisces by two Carpels (*valves*) separating from below upwards, leaving a thin plate or *replum*, with two rows of seeds, in the middle.

(4) **Silicula** of *Candytuft.*

The fruit has got the same structure as the fruit of Mustard, but it is short, broad and flattened.

(5) **Capsule** of *Poppy.*

The fruit is derived from a multicarpellary pistil. The dehiscence is by means of minute pores below the lobed stigmatic disc.

Note the dehiscence in the capsules of *Cotton plant* and *Datura* ; it is by means of longitudinal slit.

III. **Simple dry Schizocarpic fruits.**

(1) **Lomentum** of *Acacia.*

It is a pod, which becomes constricted at short intervals; each constricted off portion contains one seed. The single seeded parts may break off.

(2) **Cremocarp** of *Fennel.*

The fruit breaks into two indehiscent single seeded parts, which keep attached at their tips to a central *carpophore.*

(3) **Carcerulus** of *Althea rosea* (vern, *Gul-i-Khera*).

The mature fruit splits into many one-seeded parts, which are enclosed for some time within the persistent calyx. The one-seeded parts are indehiscent.

(4) **Regma** of *Geranium.*

The fruit breaks up into 5 one-seeded parts, which keep hanging from the top of a central carpophore by means of styles.

Examine the fruit of Castor-oil plant.

(5) **Double samara** of *Acer.*

It has two portions, each provided with a wing. The parts separate from each other and are dispersed by their wings.

VI. **Succulent fruits.**

1. **Fruit of Mango.**

Cut the fruit transversely and note that there is a thick outer coat—the *epicarp*, the middle edible juicy layer—the *mesocarp*, and the inner hard stony layer—the *endocarp*, enclosing a seed. These three layers are the differentiations of the pericarp, and the fruit is known as *Drupe*. It is derived from a monocarpellary pistil.

Other examples are the fruits of *Peach*, *Plum*, *Almond*, *Apricot*, *Cocoanut*, and *Walnut*.

2. **Fruit of Zizyphus** (vern, *Ber*).

Note the differntiations of the Pericarp into three layers. Cut open the seed and note two loculi, indicating its origin from a bicarpellary pistil. This fruit is also a *Drupe*.

3. **Fruit of Water-melon.**

Cut the fruit and note the outer, hard, green epicarp ; a fleshy seedless mesocarp ; and the central fleshy endocarp containing seeds. The mesocarp and the endocarp are edible. The fruit is a *Berry*.

Study the berries of *Tomato*, *Brinjal*, *Guava*, and *Banana*.

4. **Fruit of Apple.**

Cut the fruit transversely and note the thick outer edible portion enclosing a central five-chambered area (*Core*) with cartilaginous walls. Each chamber encloses a seed. The central part is derived from the pentacarpellary ovary, and the outer edible part is differentiated from the wall of the thalamus in the epigynous flower. Such a fruit is known as *Pome*.

The terms epicarp, mesocarp and endocarp are not applicable in this case, because the succulent parts are not morphologically the same.

V. **Aggregate Fruits.**

They are collections of fruitlets, derived from the apocarpous ovary in a single. flower.

1. **Etaerio of Achenes** —*Butter cup.*
2. **Etaerio of Follicles** —*Calatropis (Ak)*
3. **Etaerio of Drupes**—*Rubus* (*Blackberry*).

VI. **Composite fruits**

1. **Fruit of Fig.**

The fruit is derived from a hollow, pear-shaped inflorescence. Note the small achenial fruits on the inner side. Such a composite fruit is known as *Syconus.*

2. **Fruit of Pine-apple and Mulberry.**

The fruit is derived from a spike. In Pine-apple the edible part is differentiated from the axis of the spike, and in Mulberry, the perianth leaves in the female flowers become juicy. Such a fruit is *Sorosis.*

APPARATUS FOR STUDY OF HISTOLOGY.

I. The **Microscope.** It is used to magnify the structures to be seen. The object is placed on a glass slide, preferably in a drop of water, and it is so arranged on the stage, that the maximum light can be directed on to it, by the mirror. The lower end of the body tube carries a movable nose-piece, to which are fitted a low, and a high power lens. The upper end of the body tube carries an *eye piece* or *occular*, through which one sees. The body tube may be raised up or down to focus the lens on the object, by means of a coarse or a finer adjustment screw.

The microscope is a very costly apparatus and should, therefore, be used with care.

II. **The Dissecting Microscope** is a mechanism to hold a simple hand lens for focussing an object placed on a stage. This enables one to place an object on the stage and break or tease it out for study as one sees through the lens.

III. **The Binocular** is a more efficient dissecting microscope. It has two eye pieces and the student can use both of his eyes, without any strain.

HISTOLOGY.

(1) **A plant cell.**

Take a little of the white pulp from a ripe Jujube fruit (vern, *Bér*). Mount it in a drop of water and irrigate it with a drop of iodine solution. Focus the slide under the microscope.

Note single isolated cells. A cell has a clear boundary line or cell wall, enclosing living substance or *Protoplasm*, in which there is a conspicuous nucleus.

(2) Remove a strip of the epidermis from the inner leaf base of Onion. Note the numerous similar cells lying close by to form a tissue.

(3) Cut a strip with a razor from a Potato and focus. Note that the cells are full of numerous starch grains. Irrigate with a dilute iodine solution, the starch grains become blue. Note the eccentric markings on the oval grains.

Try a similar strip of wheat. The grains are spherical and have concentric markings.

(4) Cut the strips of the cotyledon of Almond or endosperm of Castor-oil. Mount and see that it gives a dull oily appearance. Irrigate it with a mixture of equal parts of ether and absolute alcohol; the oil is dissolved out and the dull oily appearance gives place to a transparent view.

(5) Cut and mount sections of the pulp of Pear or that of the Phylloclade of Opuntia. Note the mineral deposits.

(6) Mount a leaf of a fresh Moss. Note that the cells are filled with small green bodies or *plastids*, containing chlorophyll or the green colouring matter (*Chloroplasts*).

(7) Mount a few root hairs of a freshly dug out plant. Note a tubular structure with distinct cell walls, protoplasmic lining and the nucleus.

(8) **Sieve tube tissue.**

Examine the L. S. of the stem of *Cucurbita* and note that in the phloem tissue, there are wide, elongated cells with perforated transverse or slightly oblique partitions (*Sieve plates*). Sketch.

(9) **Tracheal tissue.**

Examine the L. S. of the stem of *Cucurbita* or of *Helianthus*. Note the annular, spiral, reticulate and the pitted thickening, the latter is found in metaxylem.

HISTOLOGY OF THE STEM.

(1) Structure of young Dicotyledonous stem (*Sun-flower plant*).

Examine the T. S. of the stem with a pocket lens, and note the circular ou..... ..ad a number of the vascular bundles arranged in a ring around the central pith. Now examine the section under the low power of the microscope and note the following :—

(*a*) The outermost layer of the cells forming a continuous *epidermis.*

(*b*) The many-layered tissue of thin-walled parenchymatous cells forming the *cortex*, which is differentiated as *hypoderma* underneath the epidermis. The innermost layer of the cortex is known as the *endodermis.* Its oval cells can be distinguished from the surrounding cells.

(*c*) A number of vascular bundles arranged in a ring.

(*d*) The thick walled, lignified cells lying between the endodermis and the vascular bundles constitute *Pericycle.*

(*e*) The strips of parenchymatous cells between the vascular bundles constitute the *medullary rays.*

(*f*) The central mass of the thin-walled parenchymatous tissue is the *pith.*

Focus one vascular bundle and note that it has two parts with a *fascicular cambium* between the two. The outer part is the phloem and the inner is the xylem. The smaller cells of the xylem abutting on the pith are the *Protoxylem* and the outer larger xylem cells are the *Metaxylem.*

Draw the T. S. in outline and one vascular bundle.

(2) Structure of the Monocotyledonous stem.

Examine the T. S. of the stem of Maize, and note the outer epidermis, narrow cortex and a number of scattered vascular bundles. The pericycle is several layered.

Examine one vascular bundle, and note the V-shaped xylem with phloem between its arms. Small circular cavities of the protoxylem vessels and large cavities of the metaxylem vessels may also be noticed. Note that each vascular bundle has the same relative position in relation to the centre of the stem, *i.e.*, each bundle has an endarch protoxylem.

Note a similar structure in the stems of *Ruscus*, *Asparagus*, and *Grass*.

Draw the outline of the T. S. and the detailed structure of one vascular bundle.

(3) Secondary growth in the Dicot stem.

Examine a T. S. of a shoot less than a year old.

Note that the structure is the same as already studied under (1). The Cambia of every two adjacent vascular bundles have become connected across the medullary rays by the formation of meristematic cells. Note the formation of a complete cambial ring, at places passing through the bundles, and at places running across the medullary rays. Note the tissues inside and outside.

(4) Examine a T. S. of a two or three years old shoot and note ;

(*a*) The position of the vascular bundles is still indicated by the primary xylem.

(*b*) The cambial ring is widened by the addition of rings of secondary xylem outside the primary xylem.

(*c*) Note that the tissues lying outside the cambial ring (Primary Phloem, Pericycle and cortax) have been shifted out by the addition of secondary Phloem just on the outside of the cambial ring.

(*d*) Note the following tissues in order from the primary xylem groups which project into the pith :—

(*i*) Secondary xylem : note its many rings : the rings of spring wood and autumn wood alternate. The vessels of spring wood are larger than that of the autumn wood.

To obtain the age of the branch, count the number of rings and divide them by two.

(*ii*) Cambium. Note several layers of small four sided cells.

(*iii*) The secondary phloem, next to the ring of the secondary xylem. This is not distinguishable from the primary phloem which is seen in traces, just outside the secondary phloem, in the form of broken thickened cells called *hard bast.*

(*iv*) Pericycle.

(*v*) Endodermis,

(*vi*) Cortex.

(*vii*) Epidermis.

(5) **Structure of the aquatic stem.**

Examine the T. S. of the stem of *Nelumbium* (*Lotus*) and note a large number of air spaces in the cortex, and a poorly developed central vascular tissue. This is characteristic of aquatic plants.

HISTOLOGY OF THE ROOT.

(1) Examine the T. S. **of the young root of Bean** and note the following :—

(*a*) A wide cortex consisting of thin walled parenchymatous tissue with its outer layer known as the *epiblema*. Its innermost layer is differentiated as the *endodermis*.

(*b*) A single layered pericycle.

(*c*) A number of xylem bundles alternating with the phloem bundles. The xylem is exarch, *i.e.*, protoxylem to the outside.

(*d*) A central pith may or may not be present.

(2) **Aerial roots.**

Examine the T. S. of the aerial root of *Pandanus* and the *Banyan*, and note the numerous outer layers of the parenchymatous tissue known as the *Velamen*. The cortex is internal to the velamen and separated from it by the *escodermis*.

(3) **Development of rootlets.**

Examine the T. S. of the root at its branching, and note a thick zone of tissue coming out of the pericycle through the outer cortex. This type of the development of the roots is known as the *endogenous* development.

(4) **Secondary growth in the roots.**

Examine the T. S. of an old root of the Sun-flower plant. Note a number of primary xylem bundles in the centre surrounded by the secondary xylem, and the medullary rays radiating outwards from the tips of the protoxylem groups.

HISTOLOGY OF THE LEAF.

(1) T. S. of the **leaf of Sun-flower plant.**

Examine the slide and note the following :—

(*a*) Small hairs upon the epidermis which is continuous on the upper surface of the lamina.

(*b*) A row of elongated cells, at right angles to the plane of epidermis, filled with chloroplasts. This is the assimilating tissue and known as *Palisade parenchyma.*

(*c*) A *spongy parenchyma* with large inter-cellular spaces below the palisade cells.

(*d*) A vascular bundle with xylem towards the upper and phloem towards the lower surface of the lamina.

(*e*) A lower discontinuous epidermis due to the presence of stomata.

(2) **Epidermis of the Lamina.**

Remove a strip of the epidermis of the leaf of *Tropaeolum* and examine it under the microscope.

Note the numerous stomata, each having two concave-or-convex guard cells, with a hole between them.

HISTOLOGY OF THE FLOWER

1. Transverse Section of the **Anther.**

Note the two pollen sacs in each of the anther lobes. The pollen grains may further be seen in the pollen sacs.

2. Transverse section of the **Ovary of Datura**

Note the quadrilocular condition and the *axile placentation.*

3. Transverse section of the **Ovary of Poppy.**

Note that the ovary is polycarpellary and unilocular. The placentas which are septa covered with ovules, do not reach the middle of the ovary. The placentation is *parietal.*

4. Transverse section of the **Ovary of Lychnis.**

Note the central axis in the ovary. The ovules are developed on the axis and not on the wall of the carpels. The placentation is *free-central.*

KEY TO THE NATURAL ORDERS

I. Dicots :

(*a*) Corolla polypetalous (Polypetalae).

1. Petals five, cauducous; nectaries at the base, stamens as many as petals; carpels one or indefinite. *Ranunculaceae.*

2. All parts with a special sulphur smell; thick tap root; flowers tetramerous; corolla cruciform : stamens tetradynamous. *Cruciferae.*

3. Flowers pentamerous ; stamens indefinite, monadelphous ; fruit a carcerulous. *Malvaceae.*

4. Flowers pentamerous ; calyx gamosepalous; corolla irregular or regular ; stamens ten or indefinite ; carpel one ; fruit legume. *Leguminosae.*

(*i*) Flowers zygomophric.

α. Zygomorphy due to different size of the petals. *Papilionaceae.*

β. Zygomorphy due to unequal arrangement of the petals on the thalamus. *Caesalpinioideae.*

(*ii*) Flowers regular ; stamens indefinite. *Mimosoideae.*

5. All parts gland dotted ; flowers pentamerous ; calyx and corolla succulent ; stamens indefinite, polyadelphous : a large disc below the ovary ; fruit berry. *Rutaceae*

(*b*) Corolla gamopetalous (Sympetalae).

1. Corolla bilipped ; all parts aromatic ; leaves opposite and decussate ; inflorescence. verticillaster. *Labiateae.*

2. Leaves alternate, sometimes opposite in the floral region ; flowers in capitula. *Compositae.*

3. Leaves alternate ; flowers pentamerous ; stamens as many as the number of petals ; anthers yellow ; dehiscence by terminal pores forming a cone around the pistil. *Solanaceae.*

(*c*) Perianth absent, (Apetalae).

Flowers Unisexual grouped in a special inflorescence called cyathium. *Euphorbiaceae.*

II. Monocots.

(*a*) Flowers sessile, in spikelets of three or more, protected by legumes ; stamens three, carpel one ; leaves linear with parallel venation. *Graminaceae.*

(*b*) Leaves large, borne terminally (Palm habit), on an unbranched stem ; and inflorescence a spadix ; flowers trimerous. *Palmaceae.*

(*c*) Flowers usually trimerous, incomplete ; perianth of six in two series ; leaves radical. *Liliaceae.*

STUDY OF NATURAL ORDERS.

I. Family: RANUNCULACEAE.

1. Type: **Ranunculus muricatus** (*Buttercup*).

Habit: Herb.

Root: Fibrous tap root.

Stem: Herbaceous, erect, cylindrical, fistular (hollow) and glabrous.

Leaves: Alternate, petiolate, exstipulate, simple, palmatifid, multicostate reticulate.

Inflorescence: Cymose.

Flower: Solitary with opposite bract or solitary and axillary, pedicellate, complete, regular, hermaphrodite, actinomorphic and hypogynous.

Calyx: Polysepalous, 5 sepals, reflexed.

Corolla: Polypetalous, 5 petals, each petal having a pocket-shaped nectary at the base on its upper side.

Androecium: Stamens numerous, free.

Pistil: Polycarpellary, apocarpous, ovary superior, unilocular with a single basal ovule.

Fruit: Etaerio of achenes.

Seed: Albuminous.

Floral formula: ⊕, ☿, K5, C5, A∞, $\underline{G\infty}$.

2. Type: **Delphinium ajacus** (*Larkspur*).

Flowers are arranged in a typical raceme and zygomorphic. Calyx, 5 sepals, the posterior sepal drawn out into a hollow spur containing the spur of two posterior petals, which secrete honey.

Stamens numerous, pistil monocarpellary, and fruit a follicle.

II. Family : CRUCIFERAE.

Type : **Brassica compastrus** (*Mustard*)

Habit : Herb.

Root : Fibrous tap root.

Stem : Herbaceous, erect, cylindrical.

Leaf : Radical leaves lyrate ; leaves in the floral region alternate, sessile, exstipulate, simple.

Inflorescence : Corymbose raceme.

Flower : Ebracteate, pedicellate, regular, hermaphrodite, and hypogynous.

Calyx : Polysepalous, 4 sepals in two whorls, outer whorl anterio-posterior.

Corolla : Polypetalous, 4 petals, cruciform.

Andrοecium : Stamens 6, two outer short and four inner long, (tetradynamous.) A green nectary at the base of each short stamen on the inside, and a nectary between the filaments at the base of each pair of long stamens.

Pistil : Bicarpellary, syncarpous, superior ovary, bilocular due to the formation of a false septum, placentation parietal, short style and bifid stigma.

Fruit : Siliqua.

Seed : Exalbuminous.

Floral formula : ☿, K2+2, C+, A2+4, G($\underline{2}$).

III. Family: MALVACEAE.

Type : **Althea rosea** (*Hollyhock*).

Habit : Herb.

Root : Tap-root.

Stem : Herbaceous above, woody below, cylindrical, hairy.

Leaf : Alternate, petiolate, stipulate, hairy, multicostate reticulate.

Inflorescence : Axillary cymose clusters.

Flower : Bracteate, pedicellate, complete, hermaphrodite, actinomorphic, hypogynous.

Epicalyx : 5 to 6 bracts constituting an epicalyx.

Calyx : Gamosepalous, 5 lobed persistent.

Corolla : Polypetalous, 5 petals, twisted.

Androecium : Stamens numerous, united to form a long tube bearing half anthers at the top. The staminal tube coherent with the petals at the base.

Pistil : Polycarpellary, syncarpous, superior ovary, multilocular, styles as many as the carpels, projecting above the staminal tube.

Fruit : Schizocarpic, carcerulous.

Floral formula : ⊕, ☿, Epi 6, K(5), C5, A(∞), $\underline{G(\infty)}$.

IV. Family : LEGUMINOSAE.

(*i*) Sub-Family PAPILIONACEAE.

Type : **Lathyrus odoratus** (*Sweet pea*)

Habit : Climbing herb.

Root : Tap root with root-nodules containing Bacteria for the fixation of atmospheric nitrogen.

Stem : Herbaceous, weak, climbing, winged.

Leaves : Alternate, petiolate, stipulate, compound, imparipinnate, the upper leaflets modified into tendrils ; Leaflets sessile, oval, entire, unicostate and reticulate.

Inflorescence : Cymose. 1—3 flowers on a long peduncle.

Flowers : Bracteate, pedicellate, zygomorphic, hermaphrodite.

Calyx : Gamosepalous, 5 lobed, odd sepal anterior.

Corolla : Polypetalous, 5 petals, the uppermost petal is known as *Vexillum*, inner to which are two *wings* or *alae*. The two anterior petals are fused to form a *keel*.

Androecium : 10 Stamens, diadelphous, 9 fused together and the 10th posterior free.

Gynaeceum : Monocarpellary, ovary unilocular, superior, placentation marginal.

Fruit : Legume.

Seed : Exalbuminous.

Floral Formula : ☥ ☿, K(5), C5, A(9)+1, $\underline{G\,1}$.

2. Sub Family **CAESALPINIOIDEAE.**

Type : **Cassia fistula** (*Amaltas*).

Habit : Tree.

Root : Tap root.

Stem : Erect, woody, cylindrical.

Leaf : Alternate, petiolate, stipulate, compound, paripinnate, leaflets ovate.

Inflorescence : Racemose, long pendulous raceme.

Flower : Bracteate, pedicellate, irregular, hermaphrodite.

Calyx : Gamosepalous, 5 sepals, odd sepal anterior.

Corolla : Polypetalous, 5 petals, ascending imbricate aestivation.

Androecium : Stamens 10, free, of unequal sizes, staminodes may also be present, filaments curved.

Gynaeceum : Monocarpellary, ovary superior, unilocular, placentation marginal, style short.

Fruit : Cylindrical legume with transverse partitions, indehiscent.

Seed : Flat embedded in sweet pulp.

Floral formula : ↯, ♀, K(5), C5, A10, $\underline{G\ 1}$.

3. Sub-Family **MIMOSOIDEAE.**

Type : **Acacia arabica** (*Kikar*).

Habit : Tree.

Root : Perennial.

Stem : Erect, woody, cylindrical.

Leaf : Alternate, petiolate, stipulate, stipules modified into spines. Compound, bipinnate, glands present on the rachis.

Inflorescence : A cymose head resembling a capitulum from which it can be distinguished by the peripheral Young Flowers.

Flower : Ebracteate, sessile, complete, regular, hermaphrodite, actinomorphic.

Calyx : Gamosepalous, 5 lobed.

Corolla : Polypetalous, 5 petals.

Androecium : Stamens numerous, free, filaments long.

Gynaeceum : Monocarpellary, ovary superior, unilocular, placentation parietal.

Fruit : Lomentaceous legume or lomentum

Floral formula : $\oplus$, ☿, K(5) C5, A∞, $\underline{G\,1}$.

V. Family: RUTACEAE

Type: **Citrus aurantium** (*Orange*).

Habit: A small tree

Root: Perennial tap root.

Stem: Erect, woody, branched.

Leaf: Alternate, petiolate (petiole winged), exstipulate, unifoliate compound, unicostate reticulate, lamina showing numerous glandular dots which become translucent when exposed to light. Note the axillary spine which is modified first leaf of the abortive shoot.

Inflorescence: Racemose.

Flower: Ebracteate, pedicellate, hermaphrodite, actinomorphic, hypogynous.

Calyx: Gamosepalous, sepals five.

Corolla: Polypetalous, petals five or four.

Androecium: Stamens numerous, polyadelphous.

Pistil: Polycarpellary, syncarpous, superior ovary, multilocular, ovules many, axile placentation, below the ovary there is a large disc.

Fruit: Berry.

Seed: Exalbuminous.

Floral formula: $\oplus$, ☿, K(5), C5 or 4, A ∞, G $\underline{(\infty)}$.

VI. LABIATEAE.

1. Type: **Ocimum basilicum** (*Niazbo*).

Habit: Herb.
Root: Tap-root.
Stem: Erect, quadrangular.
Leaf: Opposite and decussate, exstipulate, simple, ovate, unicostate and reticulate. aromatic.
Inflorescence: Verticillaster.
Flower: Ebracteate, pedicellate, irregular, hypogynous, zygomorphic, hermaphrodite.
Calyx: Gamosepalous, 5 lobed, bilabeate, upper lip formed of one large lobe and the lower lip 4 lobed.
Corolla: Gamopetalous, 5 lobed, bilabiate, upper lip is 4 lobed and lower lip one lobed.
Androecium: Stamens 4, epipetalous, posterior stamen absent, didynamous.
Gynaeceum: Bicarpellary, syncarpous, superior, tetralocular, stigma bifid, placentation axile; disc below the ovary secretes honey.
Fruit: Schizocarp, consisting of 4 nutlets.

Floral formula: †, ☿, K(1+4), $\overbrace{C(4+1)}$, A4, G $\underline{(2)}$

?. Type: **Salvia.**

Flower: Bracteate, pedicellate, irregular, hermaphrodite, zygomorphic, hypogynous.
Calyx: Gamosepalous, 5 lobed, bilabiate, the upper lip is 3 lobed and the lower lip is bilobed.
Corolla: Gamopetalous, 5 petals, bilabiate, upper lip bilobed and the lower large and three lobed.
Androecium: Stamens 2, epipetalous, filaments short and the anther-lobes separated by an elongated connective, the anterior half-anther lobe is fertile and the inner sterile.
Gynaeceum: Bicarpellary, syncarpous, superior ovary, tetralocular, stigma bifid.
Fruit: Schizocarp consisting of 4 nutlets.

Floral formula: †, ☿, K(3+2) $\overbrace{C(2+3)}$, A2, G$\underline{(2)}$.

VII. Family : COMPOSITAE.

1. Type : **Helianthus annus** (*Sun-flower*).

Habit : Herb.

Root : Tap-root.

Stem : Erect, cylindrical, hairy.

Leaf : Alternate, petiolate, exstipulate, simple, ovate, unicostate and reticulate.

Inflorescence : Capitulum with marginal *ray florets* and central *disc florets*. Involucre consisting of numerous green bracts.

Ray florets : Ebracteate, sessile, ligulate, epigynous ; Pistilate, or neuter.

Calyx : Absent.

Corolla : Three to five lobed, ligulate.

Androecium : Absent.

Gynaeceum : Bicarpellary, syncarpous, ovary inferior.

Floral Formula : Ko, C (5) Ao, $G\overline{(2)}$.

Disc florets : Bracteate, sessile, actinomorphic, bisexual, epigynous,

Calyx : Sepals rudimentary, represented by two scale-like structures.

Corolla : Gamopetalous, 5 lobed, each lobe represented by a terminal tooth-like structure.

Androecium : Five stamens, epipetalous, synantherous.

Gynaeceum : Bicarpellary, syncarpous, ovary unilocular, inferior, with a bifid stigma.

Fruit : Cypsela.

Floral formula:—$\oplus$, ☿, Ko, $\widehat{C(5)}$, A5, $G\overline{(2)}$.

2. Type **Centaurea** (*Blue bottle*)

The capitulum has got an outer involucre consisting of many bracts. Flowers tubular. Calyx is in the form of a few hairs constituting *pappus*. Flowers hermaphrodite actinomorphic and epigynous. Stamens are epipetalous, with syngenesious anthers. Pistil bicarpellary and inferior.

VIII. Family: SOLANACEAE.

Type: **Solanum nigrum** (*Mako*).

Habit: Wild herb.

Root: Tap root.

Stem: Erect, cylindrical, herbaceous, may be woody below.

Leaf: Alternate, petiolate, exstipulate, simple, ovate, margin toothed, unicostate and reticulate.

Inflorescence: Cymose, extra-axillary rhipidium (scorpiod cyme).

Flowers: Ebracteate, pedicellate, complete, regular, hermaphrodite, actinomorphic, hypogynous.

Calyx: Gamosepalous, 5 lobed.

Corolla: Gamopetalous, 5 lobed, companulate.

Androecium: Stamens 5, epipetalous, alternating with the petals, anthers united.

Gynaeceum: Bicarpellary, syncarpous, superior, bilocular, marginal axile placentation,

Fruit: Berry.

Floral formula: $\oplus, \varnothing, K(5), \overbrace{C(5), A5}, \underline{G(2)}$.

XI. Family: **EUPHORBIACEAE.**

1. Type: **Euphorbia helioscopia.** (*Chandi bute*)

Habit: Herb.

Root: Tap root.

Stem: Erect, cylindrical, white latex present.

Branching: Multichasial cyme. The main axis of the plant ends in a cyathium and from below this 5 branches arise in the axils of 5 bracts. Each branch ends in a cyathium and from below this three branches arise with axillary bracts. Each of these branches ends in a cyathium, from below which arise again two branches and so on.

Leaves: Alternate, simple, obovate, reticulate, unicostate, entire.

Inflorescence: Cyathium. It consists of an involucre of 5 bracts, enclosing male and female flowers, glands alternating with the bracts present on the margin.

Staminate flowers:

Calyx: Absent.

Corolla: Absent.

Stamen: One.

Floral formula: Ko, Co, A1.

Pistilliate flowers:

Calyx: Absent.

Corolla: Absent.

Pistil: Tricarpellary, syncarpous ovary situated on a long curved stalk. Stigma bifid, superior.

Floral formula: Ko, Co, $\underline{G(3)}$.

2. Type: **Euphorbia splendens**

Note the stipules modified into spines. Inflorescence is cyathium enclosed by two scarlet bracts.

3. Type: **Ricinus Communis** (*Caster oil, Harind*).

Leaves, alternate, petiolate, exstipulate, peltate, palmatifid with glands on the top of the petiole. The flowers are arranged in panicle of racemes; flowers unisexual, both kinds on the same axis, female flowers above and male below; stamens branching, each branch ending in half anthers; gynaeceum, tricarpellary, syncarpous, superior, and trilocular; fruit regma.

X. Family: GRAMINACEAE.

Type: **Avena sativa** (*Oat Javi*).

Habit: Herb cultivated.

Root: Adventitious, fibrous.

Stem: Erect, cylindrical, fistular, jointed.

Leaf: Alternate with sheathing leaf base, exstipulate, simple, linear parallel venation.

Inflorescence: A panicle of spikelets. Each spikelet has got two flowers, enclosed inside two glumes.

Flower: It arises in the axil of an inferior palea, opposite to which is a boat-shaped superior palea. On a short axis, within the two palea, note two lodicules, supposed to be perianth leaves.

Androecium: Stamens three, anthers versatile. Filaments long;

Gynaeceum: Monocarpellary, superior, unilocular with one ovule, style short, stigma two, feathery.

Fruit: Caryopsis.

Floral formula: ☿, P2 (lodcules), A3, G $\underline{1}$.

XI. Family: PALMACEAE.

Type: **Phoenix sylvestris** (*Date-palm*).

Habit: A wild tree with a crown of leaves at the top.

Root: Adventitious arising from the base of the stem.

Stem: Erect, woody, unbranched, covered with persistent leaf-bases.

Leaf: Alternate, exstipulate, petiolate, leaf bases broad, compound, lowest pinnae modified into spines. Leaflets, lanceolate, with parallel venation.

Inflorescence: Spadix with large woody spathe.

Flowers: Ebracteate, unisexual, dioecious, actinomorphic, hypogynous, trimerous

Staminate flower:

Perianth: 6 segments in two whorls, polyphyllous.

Androecium: Stamens 6 in two whorls.

Pistillate flowers:

Perianth: 6 segments in two whorls, polyphyllous.

Gynaeceum: Tricarpellary, apocarpous, only one carpel develops, the other two being abortive, superior, developed carpel unilocular, placentation marginal.

Fruit: Berry.

Floral formula:—

Male flower: ⊕, P3+3, A3+3, Go.

Female flower: ⊕, P3+3, Ao, $\underline{G\ 3}$

XII. Family: LILIACEAE.

Type: **Asphodelus tenuifolius** (*Piazi, Bhugât*)

Habit: A common weed.
Root: Adventitious, fibrous.
Stem: Short and condensed.
Leaf: Radical, exstipulate, simple, cylindrical, fistular.
Inflorescence: Raceme.
Flower: Bracteate, pedicellate, regular, hermaphrodite, actinormorphic, hypogynous.
Perianth: Perianth leaves 6 in two whorls, slightly united at the base.
Androecium: Stamens 6 in two whorls.
Gynaeceum: Tricarpellary, syncarpous, superior, trilocular, placentation axile.
Fruit: Localicidal capsule.
Floral formula: ⊕ ☿ P3+3, A3+3, G($\underline{3}$).

PARASITIC PLANTS.

1. **Cuscuta** (Dodder, vern. *Akash bel* or *Amar bel*).

The vegetative part of the plant consists of long, a slender pale leafless shoots, spreading over the host plant. Note its roots (haustoria) penetrating into the tissues of the host. Examine a transverse section of the stem of the host penetrated by the haustoria of the parasite. Note the xylem and phloem of the parasite fusing with the corresponding tissues of the host plant.

2. **Mistletoe.**

It is a partial parasite, because it is partially dependent on the host, and generally grows on the branches of Oak and Poplar etc. Note the aerial shoots bearing green foliage leaves and the roots going deep into the tissues of the host plant.

INSECTIVOROUS PLANTS.

1. **Drosera.**

Note the numerous stalked glands or tentacles, on the upper surface of the leaf. The tentacles have swollen tips and secrete a sticky digestive fluid.

2. **Bladder wort** (*Utricularia*).

It is a submerged water plant, having no roots. Note the peculiar bladders borne on the submerged part of the plant. Each bladder is a modified leaf having a trap door which can be opened by a push from the outside.

3. **Nepenthes** (*Pitcher plant.*)

Note the lamina modified into a pitcher, with a lid attached to one side of the opening.

4. **Dionaea** (*Venus flay-trap*).

Note the bilobed leaves, each lobe bearing three sensitive hairs on its upper surface.

ALGAE.

Type : **Spirogyra.**

It forms large lumps of filaments floating in fresh water ponds. The filaments are slimy to touch on account of an outer mucilaginous layer. Examine a filament under the microscope and note that it is unbranched, and consists of a number of large cells placed end to end.

Each cell is a long cylindric structure, and consists of a parietal layer of protoplasm, and several chloroplasts arranged in a spiral. Add a drop of iodine solution. The nucleus will be stained brown while the pyrenoid bodies in the chloroplasts will become blue.

Examine conjugating filaments. Note the *conjugation tubes* between the cells of two filaments, lying parallel to each other and the gametes in each of the cells. The passage of gametes (contents) of the cells of one filament into the cells of the other filament, and the formation of zygospores may also be seen. Note that a filament as a whole behaves as a male or a female, inasmuch as all its cells either send or receive contents from the other filament,

Sketch a few stages in the process of conjugation.

Type : **Ulothrix.**

It is a filamentous alga growing in slowly moving fresh water, and fixed to the stones etc., by its basal colourless cells known as hold fasts.

Examine a filament under the microscope and note that the cells are broader than long. Each cell has got a band-like semi-circular chloroplast having pyrenoid bodies, which become visible by the addition of iodine solution. Zoospores if present may also be seen swarming inside the cells.

FUNGI.

Type: **Mucor.**

Note a white and fluffy mycelium on a moist loaf of bread after a few day's time. It is known as '*Ulli*' (vern). The hyphae are non-septate and branching, with granular protoplasm. The hyphae show swellings here and there. Erect branches arise from these swellings and bear *Gonidangia* at their apices. Each Gonidangium containing gonidia is cut off from the vertical hypha by a transverse wall. This wall projects into the cavity of the gonidangium as *columella.*

Type : **Rhizopus.**

It is usually passed as Mucor, from which it can be distinguished as having a rather broad basal body forming aerial branches.

Bacteria.

Type : *Bacillus subtilis* (*Hay bacillus*).

Examine a drop of hay infusion with the high power. Note the numerous small bacilli wriggling about in the fluid. The fine cilia are not clear and can be made out by special fixing and staining. Examine a bit of the scum on the surface of the infusion and note the mesogloea stage.

BRYOPHYTA

Type : **Marchantia nepalensis.**

Note that the thallus is a thick green, dichotomously divided, dorsi-ventral structure, and is attached to the soil by rhizoids. It bears gemma cups with toothed margins on the dorsal surface. Note also minute pores of the air chambers on the dorsal surface.

On the lower surface note the scales in rows on the sides of the mid-ventral line and the rhizoids in tufts.

Prepare a slide of gemmae and note that each gemma has got a biconvex body with lateral notches, borne on a short unicellular stalk. The hyaline cells and the brown oil cells in the body may also be seen.

Examine a few rhizoids. They are smooth and tuberculate. Note the peg-like projections on the inner side of the wall in the tuberculate rhizoids. The smooth rhizoids are broader than the tuberculated ones.

Note that the *archegoniophores* and *antheridiophores* bear female and male receptacles, and arise from near the notches of the lobes on the dorsal side.

Examine a T. S. of the thallus. Note the dorsal chambered and ventral compact storage portion. The air chambers open outside by air pores. Each air chamber is bounded by a single layer of cells and contains assimilating tissue in the form of vertical rows of cells.

Examine the male and the female receptacles or the models and sketch.

The male receptacle is borne on a long stalk. It is slightly lobed. Its surface shows radiating rows of ostioles and air pores of the chambers. The ventral sides of the receptacle bear scales and the rhizoids.

Examine a vertical section through one of the lobes and note antheridia arranged acropetally. Each antheridium is enclosed in a cavity opening by an ostiole. The antheridium is club-shaped and borne on a short stalk.

The female receptacle is umbrella-shaped. Note the *perichaetia* alternating with the long rays. The archegonia are borne on the ventral surface of the receptacle.

Examine a longitudinal section through the sporogonium. Note foot, seta, and capsule.

PTERIDOPHYTES.

Type : Fern

Examine the specimens of **Goniopteris**. Note that the rhizome is long and straggling, giving off adventitious roots, and large leaves or fronds at intervals. Note the young leaves folded in a circinate manner at the apex.

Examine a transverse section of the rhizome. Note the central region consisting of parenchymatous cells, and a number of strands arranged in one ring, and some thick-walled sclerenchymatous cells underneath the epidermis. Outside the main ring of strands may be seen some smaller strands which are the cut ends of the leaf traces. Note that each strand-consists of wide thick-walled xylem vessels surrounded by the phloem. This is enclosed within a several layered pericycle outside which is a single layered endodermis. Draw the section in outline and one strand on a magnified scale.

Examine a transverse section of the root. Note the central xylem with two protoxylem groups on the outside, alternating with the phloem.

Examine the fertile leaflets of :—(*i*) **Goniopteris**, (*ii*) **Pteris**. (*iii*) and **Adiantum**. Note that it (*i*) the sporangia are in small round clusters or sori uncovered by any indusium, in (*ii*) they are borne in a marginal row on the under surface of the margin of the leaflet, which is bent back on the sorus, forming a false indusium, in (*iii*) they are arranged in marginal groups protected by indusia.

Tease out a few sporangia from a sorus and examine them with the low power. Note that each sporangium has got an oval body with an incomplete ring of annulus, borne on a short stalk. Note the characteristic cells in the annulus with radial and inner walls thickened.

Examine a prothallus. Note that it is heart-shaped, with a notch at the anterior end. On the under-surface there are rhizoids and globular antheridia at the pointed end, and the archegonia arising from the cushion near the notch. Sketch.

Study the structures of the antheridium and archegonium from the models. Sketch.

GYMNOSPERMS.

Type :—**Pinus longifolia.**

It is a tall tree with branches at the top.

Examine a shoot of *unlimited growth*. Note that it is covered over with small scale leaves each of which bears a *dwarf shoot* in its axil. The dwarf shoot is small, with a few basal scales and bears a cluster of three needle-like green foliage leaves.

Examine a transverse section of the young shoot. Note the central pith, the vascular bundles in a ring and the outer thin-walled parenchymatous cortex containing resin passages. The resin passages are surrounded by a number of glandular cells, the epithelial rayer. The vascular bundles are collateral, open with protoxylem vessels towards the pith. Note the annular rings of wood and the medullary rays radiating outwards in the T. S. of an older shoot, showing secondary growth.

Examine a T. S. of the root. Note its triarch condition. Each xylem bundle has two outer protoxylum groups enclosing a resin passage and alternates with a phloem bundle.

Examine a T. S. of the foliage leaf. Note its triangular outline, an undifferentiated mesophyll and two central bundles with xylem towards the flattened and phloem towards the curved surface, inside the pericycle and endodermis. The epidermis is discontinuous due to the sunken stomata. Note an air space below each stoma and a thick-walled hypodermis under the epidermis. The cells in the mesophyl tissue are polygonal with peg-like projections on their walls. Note the transfusion tissue between the vascular bundles and the resin passages in the mesophyll tissue.

Reproductive organs:

(*i*) **Male Cone :**

The male cones arise singly in the axils of scale leaves and replace dwarf shoots in the flowering season, after which the dwarf shoots again begin to appear as before. Examine a male cone. Note that it consists of a central axis and a large number of microsporophylls arranged spirally around the axis. The tip of the sporophyll is slightly turned upwards. Note two pollen sacs on the underside of each sporophyll containing numerous microspores or pollen grains. Take out a few pollen grains and examine under the microscope. Note the two air sacs on the sides of a pollen grains

(*ii*) **Famale Cone :**

The female cones replace the shoots of unlimited growth. Each consists of a large number of thick, *ovuliferous scales* arranged around the central axis. Note a *bract scale* under each thick ovuliferous scale, at its base. It is also known as *carpellary scale*. Note two pits on the upper side of the thick scales, near the axis of the cone, indicating the position of the seeds.

Examine the L. S. of a young cone. Note the ovules the upper side of the thick scale. Each ovule is surrounded by an integument with its micropyle to the inside and the embryo sac towards the base of the nucellus.

Examine the seeds of *Pinus Gerardiana* (*Chilgoza*).

Note the thick hard outer coat and a thin membraneous inner coat. At the pointed end of the white seed, note the remains of nucellus in the form of a thin cap. Cut the endosperm and note the pointed radicle on one side and a cluster of 10 cotyledons on the other, united to form a tube. Note the plumule at the bottom of this tube.

PHYSIOLOGY

1. **Osmosis.**

Take a thistle headed funnel covered at the broad end by animal membrane and filled with a concentrated coloured solution of sugar. Invert it in a glass vessel containing water and clamp it to an iron stand. Mark the level of the solution in the funnel. Note the rise of the level due to the absorption of water from the outer vessel.

2. **Plasmolysis** or **Exosmosis.**

Examine a filament of Spirogyra in a 5% salt solution. Note the shrinking of the protoplasm due to the outward passage of water from the cells.

3. **Root-pressure.**

Take a plant in a flower-pot and cut the stem near the base. Tie a small rubber tube to the cut end, fill it with water and attach an S-shaped glass tube (with one arm longer than the other) containing mercury at the other end of the rubber tube. Mark the level of the mercury. Fix the glass tube to a stand and leave it for a day or two, water the plant as usual. Note the rise in the level of the mercury column in the longer arm, due to the upward pressure of water exuding from the cut-end of the stem.

4. **Transpiration.**

(*a*) Suspend a spring from the upper arm of an iron-stand. Tie a silken thread to the lower end of the spring, and pass it through a hole in a plate attached to the stand below. Take a glass test tube half filled with water and fit a leafy shoot into it, with its lower end dipping in water. Tie the test tube to the thread that hangs from the lower end of the spring. If a needle is attached to the thread, at the level of the plate, the loss of weight due to transpiration shall be apparent from the upward movement of the needle.

(*b*) Take a simple glass potometer with a parallel side arm. Fit a leafy shoot, which is cut under water, into the opening of the side-arm. Fix a graduated capillary tube into the lower opening of the potometer, with its lower end dipping in a dish containing water. Make the connections air tight with wax or India-rubber. Fix the apparatus to a stand. Introduce an air bubble in the capillary tube and note its upward movement.

(*c*) Take two leaves of Banyan or Rubber plant. Attach a piece of rubber tubing to the cut-end of the petiole to avoid transpiration. Paint the lower surface of one leaf (*a*) and the upper surface of the other (*b*) with vaseline. Weigh the leaves and then hang them for several days. Note the loss of weight in (*b*) which dries and shrivels and not in (*a*).

(*d*) Place a leaf between two dry filter papers soaked in 5% cobalt chloride solution and keep them flat by two outer glass pieces. Note the change of colour from blue to pink in the filter paper facing the lower surface of the lamina, indicating the loss of water through the stomata.

5. **Course of the water current :**

Cut a shoot of Balsam under water and dip the cut-end in a solution of Eosine. Note the vascular bundles becoming red as the stem is translucent.

6. **Carbon assimilation.**

(*a*) Place some water plants (Hydrilla or Spirogyra filaments etc.) under a glass funnel in a vessel containing water and expose it to bright light. Invert a test tube containing water over the funnel. Note the gas bubbles coming out of the funnel. Test the gas collected in the test tube and see if it is oxygen.

(*b*) Take a few green leaves. Boil them in water. Dissolve out chlorophyll by putting them in alcohol. Add 1% or 4% iodine solution to the bleached leaves and note the blue colour due to the presence of starch.

(*c*) Try the above experiment with the variegated leaves of Arundo donax (ver, *Nar.*), and note the blue colour in the green part of the leaf only.

(*d*) Place flower-pots under blue and red bell-jars in bright light for 12 hours. Then put one leaf of each plant to the starch test. Note that the leaf of the plant under red bell-jar shows larger amount of starch, indicating that the red part of the light is more effective in assimilation than any other part.

(*e*) Add benzol to the alcoholic extract of chlorophyll in a test tube. Shake it well. Note the two liquids again forming distinct layers. Benzol with chlorophyll forms an upper green layer, while alcohol with carotin and xanthophyll forms a lower yellowish layer.

7. **Respiration :**

(*a*) Put some germinating seeds in a flask along with the pieces of moist blotting paper, a nd a small test tube containing strong solution of caustic potash. Make it air tight. Fit a glass tube bent at right angles at two places into the flask, its other end dipping in a beaker containing water. Note the level of the water. Leave the apparatus overnight and ncte the rise of water column in the tube. This is due to the decrease of volume in the flask as the CO_2 produced by the respiring seeds, has been absorbed by KOH.

(*b*) Place some green leaves in a dish containing water under a bell jar, through which a slow current of air is passed. This air is deprived of its CO_2 by the potash in a U-tube, and is made to pass through another jar containing lime water connected with the aspirator. Note that the lime water becomes milky due to CO_2 produced by the leaves.

(*c*) **Intra-molecular Respiration :—**

Remove the testa from a few soaked gram-seeds, and introduce them into an inverted test tube full of mercury and place it in a dish full of mercury. Leave it overnight and observe some gas at the top of the test tube next morning. Test the gas and note that it is CO_2.

8. **Growth.**

(*a*) Take a few germinating seeds of Pea with straight radicles. Make transverse lines at a distance of 2 m.m. each with Indian ink. Fix the seed with a pin to the underside of a cork fitted in the jar containing water. Care should be taken that the radicles do not touch the water inside the jar. Examine the radicles after 24 hours, and note that the marks are not the same distances apart. Those, a little below the apex, leave longer interspaces, showing the greatest amount of growth in length in this region.

(*b*) **Auxanometer.**

Take a silk cord and tie one end of it to the apex of a plant growing in a flower pot. Pass the cord from over the pulley attached to the stand, and to its other end a weight just sufficient to keep the cord stretched. A pointer fixed to the centre of the pulley, moves along a vertical scale showing different readings. The distance through which the pointer moves along the scale in a given time indicates the rate of growth.

9. **Heliotropism.**

Take a cardboard box with a small opening on one side to admit light. Take some saw-dust, soak it with water, and grow a few gram seeds in it, inside the box. Note that the seedlings after germination are inclined towards the opening, through which the rays of light enter the box.

10. **Geotropism.**

(*a*) Allow a pot containing a young Sun-flower plant to rest on its side instead of on its base. Note that after a day or two, the shoot curves upwards, and if the plant is dug out, a corresponding curvature will be seen in the root.

(*b*) Fix a pot like the above to the disc of a Clinostat rotating in the vertical plane. The shoot continues growing horizontally and shows no indication of a curvature. The reason is that due to the rotation of the disc, all sides of the shoot are brought under the influence of gravity uniformly, and, therefore, no one-sided response can take place.